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FACTORS AFFECTING STORAGE STABILITY OF POTATO GRANULES

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Deteriorative changes in sulfited potato granules (mashed potato powder) during storage have been studied as functions of moisture content, oxygen content of the package atmosphere, and type of container (permeable *vs.* impermeable). Both nonenzymatic browning and development of an oxidative off-flavor occurred slowly at 24°C. (75°F.). The latter change was accelerated (a) by lower moisture content over the range of 3.7 to 11.2 percent moisture, (b) by increasing oxygen content of the package atmosphere, and (c) to some extent by the use of a permeable container. The fact that both oxidative off-flavor development and oxygen absorption were somewhat retarded by petroleum ether extraction before storage indicates that the oxidative change occurs in the fat fraction of the potato.

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Because of the rapidly increasing importance of potato granules (mashed potato powder) for military feeding as well as for domestic consumption, an investigation of the storage stability of this product was initiated. The present report covers a preliminary study of one lot of commercial sulfited granules. This study was designed primarily to provide information for use in planning further work on control of the stale or rancid flavor, termed here "oxidative off-flavor". Some data were also obtained on the flavor and color changes resulting from non-enzymatic browning.

Burton (1,2)[1/] reported the development of significant amounts of oxidative off-flavor in potato granules during storage. One objective of this work was to determine whether, in the product at our disposal, the oxidative off-flavor increases with decreasing moisture content, as reported by Burton. For dehydrated dice, preliminary work in this Laboratory has indicated that moisture has no major effect over the range of 3 to 8 percent (method of Makower, Chastain, and Nielsen, 8). Another objective was to obtain direct evidence on the question whether the off-flavor originates in the fat-soluble portion of the powder. Burton's observations indicated that it does, but the evidence was indirect.

Other objectives were to determine whether the off-flavor is reduced by packing in a permeable container, and to study further the known effects of package atmosphere and storage temperature on rates of browning and off-flavor development. Observations were also made on the phosphorus and nitrogen contents of the fat-soluble fractions, and on loss of carotenoids in the powder during storage.

Material and Methods

Commercially prepared mashed potato powder was obtained through the cooperation of a manufacturer. Immediately after preparation it was packaged in hermetically sealed cans with an inert-gas atmosphere. It was then shipped without delay to this Laboratory where it was repackaged in sealed cans in nitrogen (oxygen content of the can atmosphere, less than 1 percent), and then held at 1°C. (34°F.) for 2 months until the storage tests were begun. Its moisture content was 10.7 percent, MFB (moisture-free basis, method of Makower, Chastain, and Nielsen, 8). Reducing sugars were 0.41 percent, total sugars 1.56 percent (method of Hassid, 4, 5), with clarification by the ion-exchange method of Williams, Potter, Bevenue, and Scurzi, 12). The amino-nitrogen content was 0.61 percent (Van Slyke); total nitrogen was 1.90 percent (Kjeldahl). The sulfite content was 250 ppm. (Thompson and Toy modification of the Monier-Williams method, 11).

[1/] Numbers in parentheses refer to literature cited on pages 7-8.

After preliminary vacuum drying of the entire lot at 35°C. (95°F.) to a moisture content of 4 percent, fat-solubles were extracted from a 1400-gram portion of the powder by shaking with 6 successive portions of petroleum ether (60°-90°C. boiling range). The weight of each portion of solvent was 3 times that of the powder, and the periods of shaking were 1 hour each for the first 4 portions and 6 and 21 hours, respectively, for the 5th and 6th portions. Fat-solubles extracted by this procedure were 0.10 percent of the dry weight of the powder. This "defatted"2/ powder was subsequently used in the storage tests.

Solvent was removed from the "defatted" powder for the storage tests in a vacuum shelf drier at 4 mm. pressure and temperature of 32°C. (90°F.). Drying time was 24 hours; solvent removal was considered complete, since solvent could not be detected in the dry powder after 30 minutes' drying. The non-extracted powder was held in the drier with the extracted powder to equalize any possible loss of volatiles. The moisture content was 3.7 percent. The defatted powder was then adjusted to 7.1 percent moisture, MFB; the non-defatted powder was divided into three portions, which were adjusted to moisture contents of 3.7, 7.1, and 11.2 percent, MFB, respectively. Moisture adjustment was by water vapor in vacuum, the calculated amount of water being vaporized in one part of an evacuated system and absorbed by the powder in another part.

Size 211 x 200 cans were used as containers for most of the samples; each was filled with 110 grams of powder (MFB). Package atmospheres were nitrogen (0.2-0.4 percent O_2), air, and oxygen, the latter for accelerated tests. Nitrogen and oxygen atmospheres were obtained as described by Legault, Talburt, Mylne, and Bryan (7).

To test the effect of a permeable container on keeping qualities, 90-gram samples of 11.2 percent moisture content were placed in metal containers of 4-inch diameter and 1-inch height; these were covered with facial tissue. This very porous material was used to represent the most permeable container that might be used. Essentially the same moisture content was maintained throughout the storage period; after 8.5 months' storage the moisture content had increased by 0.3 percent.

2/ Only about a fourth of the total petroleum-ether solubles were removed by this procedure. Only partial extraction was expected, because it is known that in various plant materials part of the lipids are often "bound" to other constituents of the material; for example, for wheat flour, Olcott and Mecham (9) have reported the preferential binding of phospholipids. Ethanol will extract the bound lipids, but it was not used in this case because it would also have removed non-lipid substances. Further exhaustive extractions of a sample of the "defatted" powder with petroleum ether yielded an additional 0.05 percent of oil and a potato residue from which, on ethanol extraction, a further 0.20 percent of petroleum ether-soluble material was obtained. This latter "bound" fraction had a nitrogen:phosphorus ratio of 4.3, whereas the "free" fractions had a ratio of 1.1, indicating a significant difference in their chemical natures.

Storage of most of the samples was at 24°C. (75°F.). Controls were held at -34°C. (-30°F.) in nitrogen. Some of the samples were also held at 50°C. (122°F.) for demonstration of browning. All were stored in the dark.

Samples were withdrawn from storage after periods of time indicated in the tables. Determination of pressure and analysis of the atmospheres of the cans were made by apparatus and techniques to be described elsewhere. For greater precision the sample-measuring burette of the portable Orsat was replaced with a burette which could be read to about 0.05 ml. Measurements were reproducible within about ±0.1 ml. Non-enzymatic browning was estimated by the "soluble color" procedure (6).

Organoleptic appraisal was performed as follows: Sixty grams of cold milk was added to 180 ml. of boiling distilled water. To this mixture was gradually added 48 grams of potato powder while the mixture was stirred with a fork. The samples were kept warm by being held in a pan over hot water. Samples were served within 30 minutes of preparation.

A control (the same original material as the experimental samples, but nitrogen packed and stored at -34°C. (-30°F.) throughout the storage period) was served both labeled and blind in the series each day. The labeled control was assigned a score of 7 for each of two factors, scorched flavor and off flavor. Coded samples were scored from 1 to 7 (1 representing much scorched or oxidative flavor and 7 none). A sodium vapor light was used in the tasting room to eliminate color differences in samples. Water rinse between samples was optional. Fourteen experienced potato tasters were given two trial tastings prior to this particular series of samples. Nine to 11 judges were present each day of the experimental series.

Four to six tastings by the judges were carried out on each series of samples. The replicates for each judge were averaged and these averages were used in the analysis of variance procedure (10). When the F value, according to the analysis of variance, was significant at the 5 percent level, the least difference significant at the 1 percent level was calculated.

Results

Effects of Moisture Content and Oxygen: The data in Table 1 show that oxidative off-flavor occurs in significant amount in air-packed potato granules, and that it increases with decreasing moisture content. Burton's results were thus confirmed. A significant amount of browning (scorched flavor) occurred in the sample with 11.2 percent moisture content. Thus even at temperatures as low as 24°C. (75°F.) potato granules must be protected against browning as well as against oxidative off-flavor if high quality is to be maintained during prolonged storage.

Table 1 also shows that the off-flavor is inhibited by nitrogen and greatly accelerated by oxygen; this suggests that oxygen-packing may be used to advantage for accelerated tests of factors affecting rate of oxidative off-flavor development.

Table 1. Effects of moisture content and package atmosphere on oxidative off-flavor, non-enzymatic browning, and gas changes. Potato granules (non-defatted) held 7 months at 24°C. (75°F.).

	Organoleptic appraisal[a]			Gas changes	
Storage conditions	Oxidative off-flavor	Scorched flavor	Browning, optical density b/	O_2 absorbed, ml. NTP/gm. MFBx10^2	CO_2 evolved, ml. NTP/gm. MFBx10^2
		Atmosphere as variable			
O_2, 7.1% H_2O[c]	2.8	6.4	0.224	36[d]	2.5
Air, 7.1% H_2O	5.2	6.7	0.229	8.6[e]	2.0
N_2, 7.1% H_2O	6.1	6.7	0.229	0	1.4
Control, unlabeled	6.4	6.9	0.222	0	0
LD, 5%[f]	0.9	0.4	--	--	--
LD, 1%[f]	1.3	0.5	--	--	--
		Moisture content as variable			
11.2% H_2O,[c] air	6.2	5.6	0.271	5.0[e]	2.9
7.1 " "	5.8	6.6	0.229	8.6[e]	2.0
3.7 " "	4.5	6.8	0.225	9.3[e]	1.0
Control, unlabeled	6.5	7.0	0.222	0	--
LD, 5%[f]	0.7	0.5	--	--	--
LD, 1%[f]	0.9	0.6	--	--	--

[a] Labeled control was labeled score 7 for both oxidative off-flavor and scorched flavor.

[b] Optical density: 5 gm. potato powder (MFB) per 100 ml., 55 vol.% ethanol-water solution, 2-cm. cell, 390 millimicron color filter.

[c] Moisture-free basis.

[d] Amount O_2 initially present, 49 ml. NTP/gm. MFB.

[e] Amount O_2 initially present, 10.4 ml. NTP/gm. MFB.

[f] Least difference significant at 5% or 1% level. (e.g., if LD 5% is 0.4, this or a greater difference between any two scores is statistically significant at the 5% level.)

Preliminary spectrophotometric examination of appropriate extracts (3) showed that carotenoids are destroyed much more rapidly in the oxygen- and air-packed samples than in those stored in nitrogen.

Effect of Petroleum Ether Extraction: Rate of oxidative off-flavor development was somewhat reduced by the petroleum-ether extraction prior to storage (Table 2). Oxygen absorption was also reduced by the extraction. These results are direct evidence that off-flavor is due to fat components. Since only about one-fourth of the fat-soluble material was removed by petroleum ether, it could not be expected that development of off-flavor would be completely prevented. The result suggests that oxidative off-flavor might be controlled by incorporation of an appropriate antioxidant.

Table 2. Effect of petroleum ether extraction before storage for 7 months at 24°C. (75°F.) in oxygen. Potato granules containing 7.1 percent moisture, MFB

Sample	Oxidative off-flavor	Scorched flavor	Oxygen absorbed, ml. NTP/gm. MFB x 10^2
Solvent extracted	4.1	6.9	29[a]
Not extracted	3.3	6.8	36[a]
Control (not labeled)	6.6	7.0	0
LD, 5%	0.9	--	--
LD, 1%	1.3	--	--

[a] Amount O_2 initially present, 49×10^{-2} ml. NTP/gm. MFB.

Table 3. Effect of permeable container on oxidative off-flavor. Potato granules (non-defatted) held 8-1/2 months in air at 24°C. (75°F.)

Storage conditions	Oxidative off-flavor	Scorched flavor
Permeable container, 11.6% H_2O	5.4	6.1
Tin container, 11.2% H_2O	6.0	6.0
Tin container, 7.1% H_2O	5.2	6.6
Control (not labeled)	6.5	6.8
LD, 5%	0.6	0.4
LD, 1%	0.8	0.6

Effect of Permeable Container: In this experiment the permeable container increased somewhat the development of the oxidative off-flavor (Table 3). This was unexpected because of reports that a permeable container permits escape of the off-flavor. A possible explanation is that in such a container a higher oxygen content is maintained in the atmosphere surrounding the product. In these samples it was found that little or no off-odor was present in the samples in the permeable containers, although considerable off-odor was present in those in tin. This escape of off-odor but not of off-flavor as judged by taste suggests the development of two different types of reaction products--a volatile one responsible for the off-odor and a nonvolatile or less volatile product primarily responsible for the off-flavor.

Effect of Temperature: Demonstration of the effect of temperature on type of flavor change is shown in Table 4. At 24°C. (75°F.) the principal change is development of scorched flavor (browning).

Effect of Moisture on Browning: Table 5 shows the effect of moisture content on rate of browning and demonstrates the marked protection against browning that can be obtained by reduction of the moisture content.

Table 4. Effect of temperature. Potato granules (non-defatted) containing 7.1 percent H_2O MFB

Storage conditions	Oxidative off-flavor	Scorched flavor
1 month at 50°C. (122°F.), air-pack	6.1	4.4
8 months at 24°C. (75°F.(" "	5.7	6.7
Control (not labeled)	6.6	6.8
LD, 5%	0.7	0.8
LD, 1%	0.9	1.1

Summary

Deteriorative changes in sulfited potato granules have been studied as functions of (a) moisture content, (b) oxygen content of the package atmosphere, and (c) type of package (permeable *vs.* nonpermeable). The effect of petroleum ether extraction before storage has also been studied.

Table 5. Effect of moisture content on browning of potato granules (non-defatted) in air at 50°C. (122°F.)

H_2O MFB %	Change in optical density[a]	
	45 days at 50°C.	99 days at 50°C.
3.7	0.045	0.135
7.1	0.245	0.780
11.2	0.731	1.51

[a] In previous work with dehydrated dice, "limit of palatability" was reached with optical density change of approximately 0.175 unit.

It is confirmed that both nonenzymatic browning and oxidative off-flavor occur in air-packed potato granules at 24°C. (75°F.) and that the oxidative off-flavor decreases with increasing moisture content over the range of 3.7 to 11.2 percent moisture. Browning increases with increasing moisture content.

Oxidative off-flavor was very pronounced in oxygen-packed samples, and oxygen packing is suggested for accelerated tests.

Packing in a permeable container increased somewhat the oxidative off-flavor.